PI CONTROLLER FOR BATTERY CHARGER SYSTEM

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To my beloved mother and father,

Faridah Bt Che Hamat,

Azmi Bin Ibrahim.

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ABSTRACT

There are many type of battery charger that had been developed for century. However there are also many charger that not suitable to use due to the method of charging and the safety during the charging process. Normally the charger will automatically charge the battery pack when it is connected to the charger, but it keeps charging even though the battery is fully charged. This situation can damage the battery itself or the user if explosion occur during the process. Beside that, the lifetime of the battery is also important. A good charging method can increase the lifetime of the battery. PI controller can control the output voltage from the charger to meet a desire value by controlling the rise time of the current, overshoot and error that occur during charging process. The Proportional (P) action will decrease the rise time and decrease error while Integral (I) action will eliminate the error occur. This project is developed to investigate the action of PI controller to the output from battery charger.

ABSTRAK

Sejak dulu lagi terdapat banyak pengecas bateri yang telah dicipta. Walaubagaimanapun, masih terdapat banyak pengecas yang tidak sesuai digunakan berdasarkan kaedah mengecas dan keselamatan semasa proces mengecas berlangsung. Kebiasaannya pengecas ini akan mengecas bateri secara automatik apabila bateri disambaungkan pada pengecas, tetapi ia tetap mengecas bateri tersebut walaupun ia telah dicas sepenuhnya. Keadaan ini akan menyebabkan kerosakan pada bateri tersebut dan juga membahayakan pengguna sekiranya berlaku letupan akibat terlebih cas. Selain itu, jangka hayat bateri tersebut juga amat penting. Kaedah mengecas yang baik boleh meningkatkan lagi jangka hayat bateri. PI controller boleh mengawal keluaran dari pengecas dengan mengawal “rise time”, “overshoot” dan juga kesilapan yang berlaku semasa proces mengecas dijalankan. Proportional (P) akan memberi kesan dengan mengurangkan “rise time” manakala Integral (I) akan menghapuskan sebarang ketidakstabilan yang berlaku. Projek ini amat berguna untuk tujuan sistem kawalan.

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C	-	Capacitor
D	-	Duty cycle
DC	-	Direct Current
D_m	-	Freewheeling diode
f	-	Frequency
$G(s)$	-	Transfer function
i_o, I_a	-	Output current
i_c, I_c	-	Capacitor current
i_L, I_L	-	Inductor current
i_s, I_s	-	Input current
IC	-	Integrated Circuit
K_d	-	Derivative gain
kHz	-	kilo Hertz
K_i	-	Integral gain
K_p	-	Proportional gain
L	-	Inductor
mH	-	mili Henry
MHz	-	mega Hertz
MOSFET	-	metal–oxide–semiconductor field-effect transistor
ms	-	mili second
Q, M	-	Transistor
R	-	Resistor
rad/s		radians per second
t, T	-	time
V	-	Volt
V_o, V_a	-	Output voltage

V_c	-	Capacitor voltage
VLSI	-	Very-large-scale-integration
V_s	-	Input voltage
μF	-	micro Farad
μs	-	micro second
Ω	-	Ohm

LIST OF APPENDICS

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will explain about the overview of battery charger, Proportional-Integral (PI) controller, objective of the project, project scope and the thesis outlines. This project is useful for control purpose.

1.2 Objective of the Project

The main objective of this project is to develop a PI controller for a battery charger to control the transient response of the system. Beside, this project is about to investigate the action of the PI controller to the output response of the battery charger.

1.3 Scope of the Project

This project is focus on the PI controller from developing to attaching it to a battery charger. Although the scope is to focus on PI controller, but a battery charger designing is required whether a simple battery charger or advance. So a DC-DC buck converter is developed as the battery charger.

1.4 Problem Statement

Today's technologies had shown a drastic changing in all section due to its developments. Many systems had been created for this purpose. In the battery industries, there are lot of battery charger that been developed to drive a good charging process. However there are still many chargers that are not suitable to use that may damage the battery itself or the user. A bad charging process may shorten the lifetime of the battery and more dangerous is the battery may explode. A control system should be developed to overcome this problem.

1.5 Project Background

This section describe about an overview of battery charger system and PID controller.

1.5.1 Overview of Battery Charger

A battery charger is a device used to recharge the rechargeable battery. There are many types of battery charger that have been developed based on the global usage of battery source. A battery charger consists of simple battery charger, trickle, timer-based, intelligent and fast battery charger. A simple battery charger works by connecting the DC power source to the cell or battery that being charge and normally takes a long time to finish the charging process.

In this situation, an over charging might occur due to unmonitored process. Trickle battery charger used a simple battery charger that charges the battery slowly at the self-discharge rate. By leaving a battery in a trickle charger will keep the battery top-up without over charging occur. A timer-based battery charger will operate due to the pre-determine time. Usually this charger has been set to operate with a specific battery type according to a charging time. An intelligent battery charger can monitor the charging process by monitoring the battery voltage, temperature, and time under charge to determine the optimum current at that instant. When the combination of voltage, temperature, and time indicate that the battery had been fully charged then the charging process will stop.

Nowadays, a lot of equipment are using the battery source and there many issue occur related to charging process and the normal issue is over charging and the battery life is shorten that it suppose to be. Beside the monitoring the charging process, we should aware about charging technique. A bad charging technique may cause over charging and also shorten the lifetime of the battery. There are three step that drive to a good charging process which is getting the charge into the battery (charging), optimizing the charging rate (stabilizing), and know when to stop the charging process (terminating).

1.5.2 Overview of Proportional-Integral-Derivative (PID) Controller

The term Proportional-Integral-Derivative (PID) and Fuzzy-Logic is very popular and always being used in control system. PID controller consists of three control action which is Proportional action, Integral action, and Derivative action. The proportional action will have the effect of reducing the rise time and steady-state error but never eliminate this error. The Integral action will eliminate the steady-state error but it may make the transient response become worse. The Derivative action will increase the stability of the system, reducing the overshoot, and improving the transient response.

1.5.3 Basic Form of PI controlled Battery Charger

Basically the form of battery charger consists of rectifier and regulator however for this PI controlled battery charger it's consist of rectifier, DC-DC converter (regulator), and PI controller. The Figure 1.1 shows the form of this battery charger.

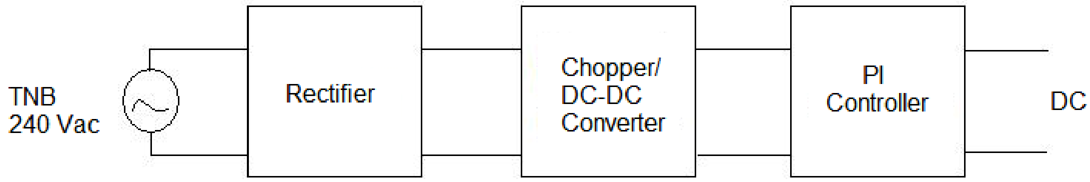

Figure 1.1: Basic Form of PI controlled Battery Charger

1.6 Thesis outline

This thesis consists of five chapters. Chapter 1 illustrate about the objective and the scope of the project, problem statement, and the background of the project.

Chapter 2 will review about the DC-DC buck converter and its operation and further explanation about PID controller.

Chapter 3 will explain about the methodology of the project including modeling and designing the DC-DC Buck Converter, PI controller, and the complete circuitry.

Chapter 4 will discuss about all the result from simulation and hardware result.

Chapter 5 will discuss about the conclusion from this project and also the recommendation for future development and modification.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will review in detail about the element that had been used in this project such as DC-DC power converter and PID controller.

2.2 DC-DC Buck Converter

The most common power converter and always been used by power supply designer is buck converter also known as step-down converter. It is normally used because the output voltage V_o is always less than the input voltage V_s in the same polarity and it is not isolated from the input.

The buck converter circuit is a one of switch mode regulator. It uses a power transistor such as MOSFET, IGBT, and others as the switching element and commonly controlled by pulse-width-modulation (PWM). This converter also uses an inductor and a capacitor as energy storage elements so that energy can be transferred from the input to the output in discrete packets. The advantage of using switching regulators is that they offer higher efficiency than linear regulators. The one disadvantage is noise or ripple; the ripple will need to be minimized through careful component selection. The basic circuit for buck converter is shown by Figure 2.1.

To reduce output voltage ripple, the switching frequency should be increased but this lowers efficiency. This means that the selection of the switching devices will be an important issue. The output voltage ripple can also be reduced by increasing the output capacitance; this means a large capacitor in practical design. It also can be reduce by adding some device that function as filter. Normally some designers add some control system which the output voltage can be controlled such control the ripple voltage.

The state of the converter in which the inductor is never zero for any period of time is called the continuous conduction mode (CCM). The DC-DC converters can operate in two distinct modes with respect to the inductor current i_L. Figure 2.2 describe the CCM where the inductor current is always greater than zero. When the average value of output current is low and/or the switching frequency f is low, the converter may enter the discontinuous conduction mode (DCM). In the DCM, the inductor current is zero during a portion of the switching period. The CCM is preferred in high efficiency and good utilization of semiconductor switches and passive components. The DCM may be used in applications with special control requirement because the dynamic order of the converter is reduced where the energy stored in the inductor is zero at the beginning and at the end of each switching period [1].

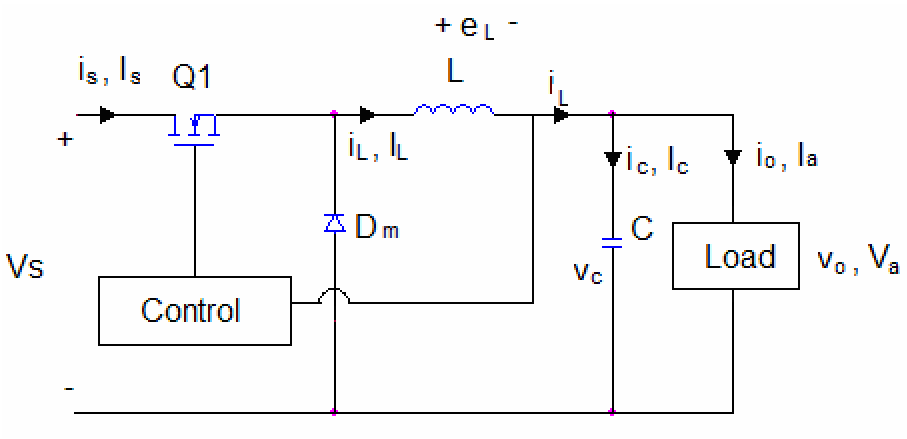

Figure 2.1: Buck Converter

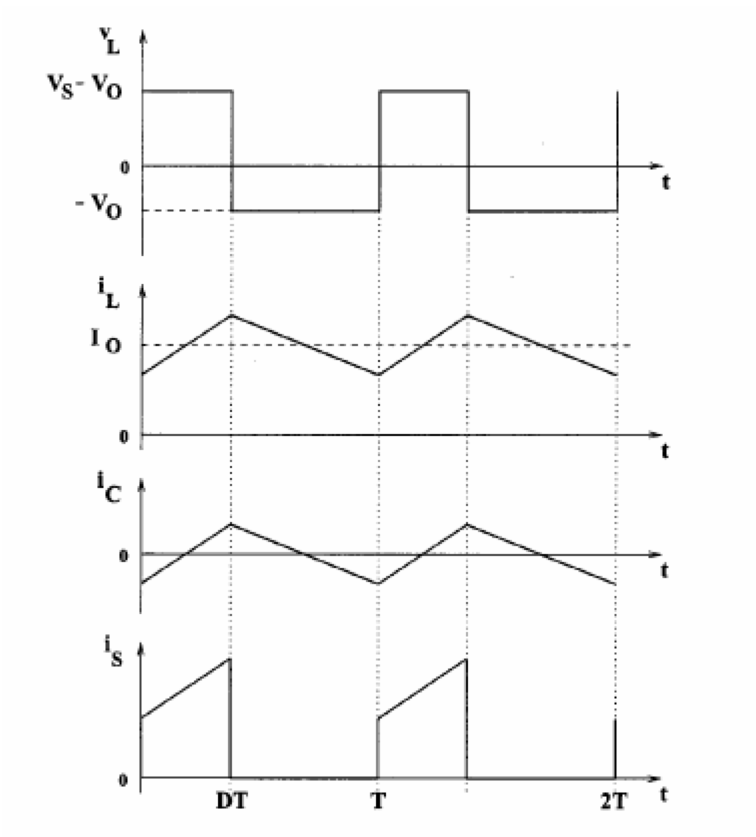

Figure 2.2: Waveforms of Buck Converter

2.2.1 Buck Converter Operation

DC-DC buck converter is the basic power converter that normally been used. This converter operates in two modes which are mode 1 and mode 2.

2.2.1.1 Mode 1 operation

Mode 1 begins when the MOSFET Q1 of Figure 2.1 is switch on at $t = 0$. In this state, the current will rise through the inductor and the energy stored in it increase [2]. During this state the inductor acquires the energy. When the MOSFET is turn ON, the diode will be in OFF state. Since the diode is there, there will always a current source for the inductor. The equivalent circuit for Mode 1 is shown by Figure 2.3.

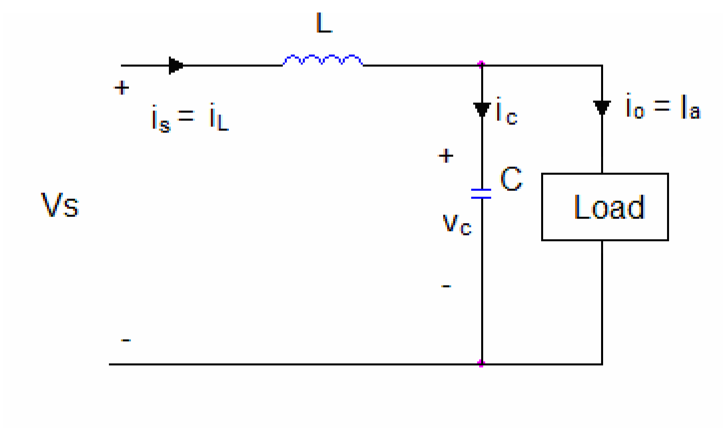

Figure 2.3: Equivalent circuit for Mode 1